Study of Ideal Dry Pipe Valve

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A STUDY

of

IDEAL DRY PIPE VALVE

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A T H E S I S

presented

by

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Fitzhugh Taylor - Prof. Fire Protection Engineering -

Howard M. Raymond.
Dean of Engineering Studies.

H41

-- T A B L E O F C O N T E N T S. --

the Ideal Dry Pipe Valve was the cause of some discussion, and naturally there was difference of opinion. The location of the defect in the first pattern of the valve and a thorough comparison of the first pattern with the second was suggested by Professor Taylor to the writers as the subject for a thesis, and during the winter term of the school year 1905-06, a series of tests upon which to base a discussion were made.

The blue print on page (9) shows the first pattern of the valve in cross section. It is divided into five (5) chambers,- A, C, E, F and G. A and F are connected by a 3/4" pipe and are under air pressure; chamber E is under water pressure, and chambers C and G are connected by a 1/2" pipe which is vented to the atmosphere. The connection between C and G is not altogether plain on account of the blue print not showing any direct connection between N and G. As shown, G apparently opens through a 3/8" hole into a channel, which is vented through N. However, this is better shown in X, which is a cross section through N, and shows that the opening above G is not a channel. In the body of the valve are two moving parts,- clap valve B which separates A and C, and movable member D, which is a solid brass shell weighing 20# 13.5 oz. when empty and 23# 14.5 oz. when full. On this brass valve are two rigid faces (P) - (Q), and one flexible rubber face (H). The two rigid faces are ground to fit the brass seats (P-Q) after the latter are in position in the cast iron body, and form the shut-off against the water pressure when the valve is set.

Assuming that the upper face plate is closed and that

D is held against its seats, any pressure turned into A is transmitted to chamber F through the 3/4" pipe connecting A to F, and acts against the bottom of the valve holding the faces against their seats. From the blue print it can be seen that pressure in F will act on an area equivalent to the area of a circle of the same diameter as the largest seat(R), and that this pressure acts against the weight of the valve added to the pressures acting on the annular rings (R. Q.) and (Q.P), and on the circle having the same diameter as the seat (P). As the chambers (C) and (G), which the seats (P) (Q) and (R) close, are connected together and vented to the atmosphere, we have the annular ring (P) (Q) remaining for the pressure in (E) to act against, and since the area of this annular ring is smaller than the area on which the pressure in (F) acts, it follows that any pressure in (F) will hold the valve against a higher pressure in (E), i.e., the valve works on the differential principle.

The second pattern submitted works on the same principle, but differs in construction. Instead of having two rigid seats, this pattern has the lower seat (Q) replaced by a brass diaphragm, and has the chambers connected differently.

(A') and (B') are connected by a 2" pipe, and (C') connects through the body of the movable member, with (G') and is vented to the atmosphere. The dimensions of the two valves differ somewhat, but not in a way to materially affect the operation. On page (24) is given a dimensional comparison of the two valves.

The results of the tests made in 1903 and early in 1904 show that there is something radically wrong with the first pattern. In "firing" with water pressures around 50#, the movable member apparently does not drop to the end of its travel, but merely opens a short distance and is immediately slammed back on its seats. When the amount of flow through the riser was small, the pressure in (A) slowly became equal to that in (E), and when the discharge from the riser was quickly opened a heavy water hammer was noted. Numerous theories could be brought forward to account for this action, but probably one as satisfactory as any is this:- When the valve is near the "firing" point, that is, when the total pressure on the lower part of (D) in chamber (F) approaches the total pressure acting downward on (D) in chambers (C) (E) and (G), water begins to creep past seats (P) and (Q), and, as the vent for chambers (C) and (G) is small, the pressure accumulates in both chambers, but more rapidly in (G) than in (C), on account of the larger diameter of the seat (Q). Now this pressure in (G) passes seat (R) and accumulates in (F), with the result that (D) is prevented from falling, until the pressures in the different chambers are equalized, which, when the passage from (F) to (A) is restricted in any way, can only occur slowly, or not at all when the passage is restricted and the discharge opening from (A') is large. However, if the pressures do become equalized, (D) does apparently drop to the end of its travel, otherwise, there could be no heavy water hammer when the discharge from (A)

is quickly increased. It would seem that the heavy flow from (E) to (A), when the discharge from (A) is opened wide, creates a suction which lifts (D) quickly and slams it against its seats with the result that we have a return to the point where the accumulation of pressure in (F) holds (D). In order to prove or refute this theory, it was necessary to make a series of tests on both patterns, introducing as far as possible conditions such as could easily occur in the field.

On the following pages, a description of these tests and the data taken is given.

APPARATUS USED IN TEST.

The dry pipe valve is connected in the valve stand, which is specially built for testing purposes. It consisted of 6" main with short vertical risers. The water end (E) of the dry pipe valve is connected to a vertical riser by means of an elbow, properly bolted. The other outlet of the valve (A) is connected to the air side of the system by a 4" vertical riser. The 6" main obtains its supply from a 4500 gallon pressure tank. A 500 gallon Quimby screw pump, driven by a 50 H.P. General Electric motor, supplies the pressure tank. The pump takes its suction from a 12,000 gallon cistern through an 8" suction pipe. The air side of system also has a 6" main with a stand pipe 70' high forming an air cushion, as is found in a sprinkler system. The 6" main discharges into the cistern, valves of the quick closing type control the discharge. The maximum safe pressure to which the system can be subjected is 125#; relief valves on the pump open at this pressure to prevent any accident to system.

The method of conducting the tests is as follows:-

The two patterns were first operated in their normal condition, i.e., the first pattern with a 3/4" by-pass and the second pattern with a 2" by-pass. The work done by the Underwriters' Laboratories on the two patterns showed that the first pattern was inoperative, but not so with the second. Our work so far with the two patterns gave us the same results. Suspecting that the by-pass between the two chambers (A) and (F) was the probable reason for difference in action of the two patterns, we used different size by-passes between the two

chambers in both patterns. In the first pattern 3/4" and 2" by-passes were used; in the second pattern, 1/2", 3/4", 1", 1-1/4", 1-1/2" and 2" by-passes were used. The construction of the first pattern was such that the 2" by-pass could not be interchanged with the 3/4" by-pass. The upper opening (K) was 2" and the lower opening (L) 3/4". It was therefore necessary to connect the lower end of 2" by-pass to bottom chamber. This was done by drilling a 2" hole in bottom of chamber, and finding -- it desirable to know the difference in pressure between the upper and lower chambers, a mercury gauge was placed in between the two chambers. The mercury gauge consists of a U tube, calibrated to read in pounds pressure per sq. inch. The right arm of the mercury gauge was connected to the upper chamber by means of a rubber tube, and the left arm to the lower chamber,- also by means of a rubber tube. This method of connecting up the mercury gauge was maintained the same throughout the series of tests.

To set the valve for operating, the clapper (B) in chamber (A) is seated and the hand plate covering the open side of this chamber is bolted in place. Next the movable member is held up in place against its seats and the air pressure turned on the system. The air pressure acts on the under side of the movable member (chamber F) and only a few pounds are necessary to hold it in place against gravity. (For gravity trip point see data sheet). The next step is to bolt on the face plate on chamber (E). When the air pressure is high enough, the water pressure is turned on. The water enters through (E) and acts on an annular ring. (See blue print of

valves, also details of construction.

The valve is now ready to be tripped or "fired". This is done by slowly releasing the air pressure in the system through a discharge valve. When the pressure on the upper side of the movable member is just greater than the pressure on the under side, the movable member drops to bottom of chamber (F) and water flows into system. The air and water pressures and mercury gauge readings are noted at time of "firing" and recorded. The readings are corrected from the gauge calibrations. The pressure is allowed to equalize in the system; the time necessary to do this is also recorded. When the pressure has equalized, a discharge valve is suddenly opened, greatly increasing the flow through the valve. The object of suddenly increasing the flow through the valve is to pick up the movable member. This is parallel to what happens in a sprinkler system when a large number of heads open at once, the flow is considerably increased.

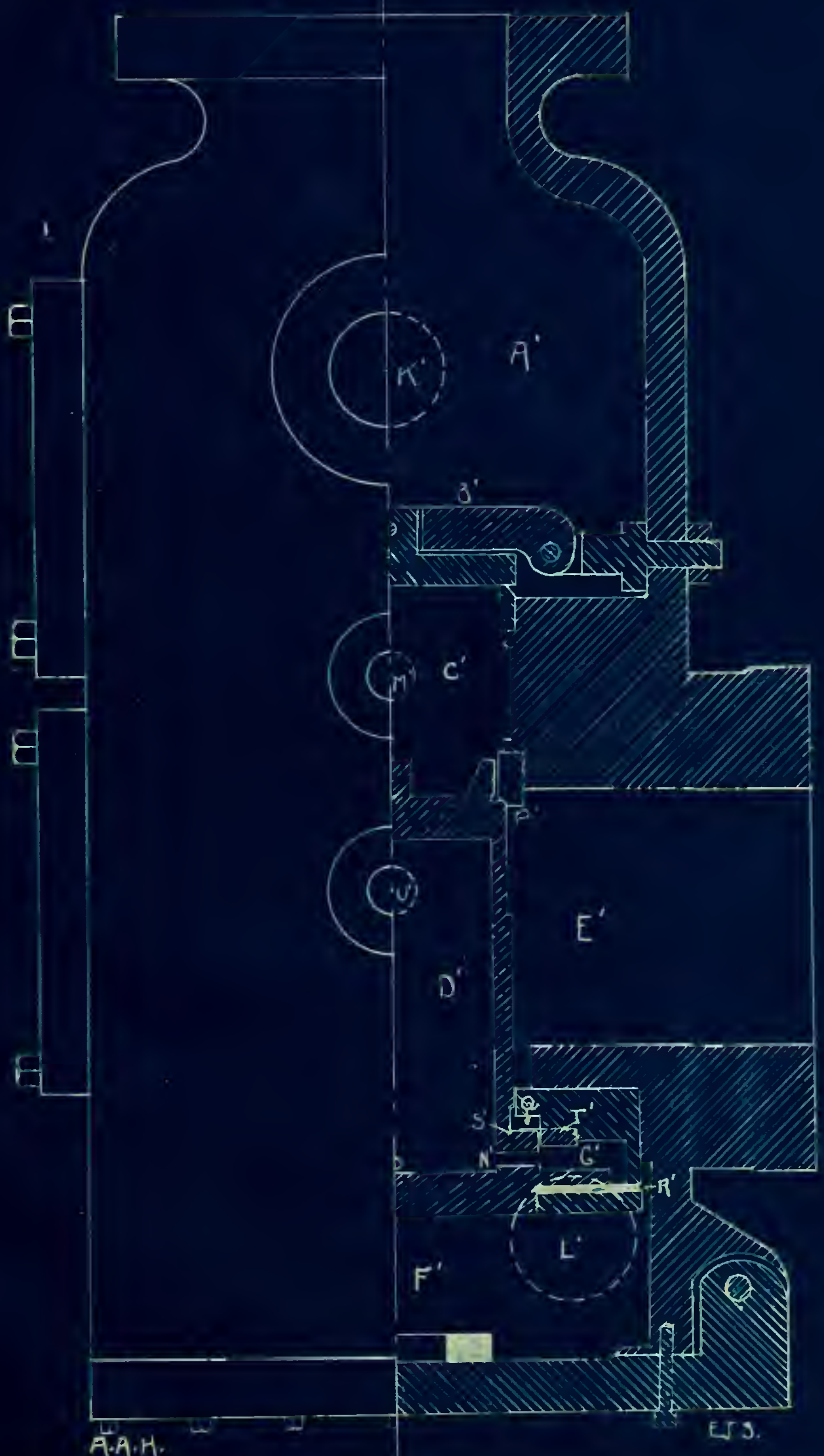
Each pattern of the valve, using the size by-passes already mentioned, and with water pressures of 15#, 25#, 40#, 50#, 75#, 100# and 125# was subjected to the above tests. The data was carefully recorded, and from the air and water pressure readings a curve of "firing" points drawn with the air pressure on the vertical axis 4# per inch and the water pressure on horizontal 20# per -- in.

IDEAL DRY PIPE VALVE
FIRST PATTERN.

PLATE 1.

IDEAL DRY PIPE VALVE.
SECOND PATTERN.

PLATE 2.



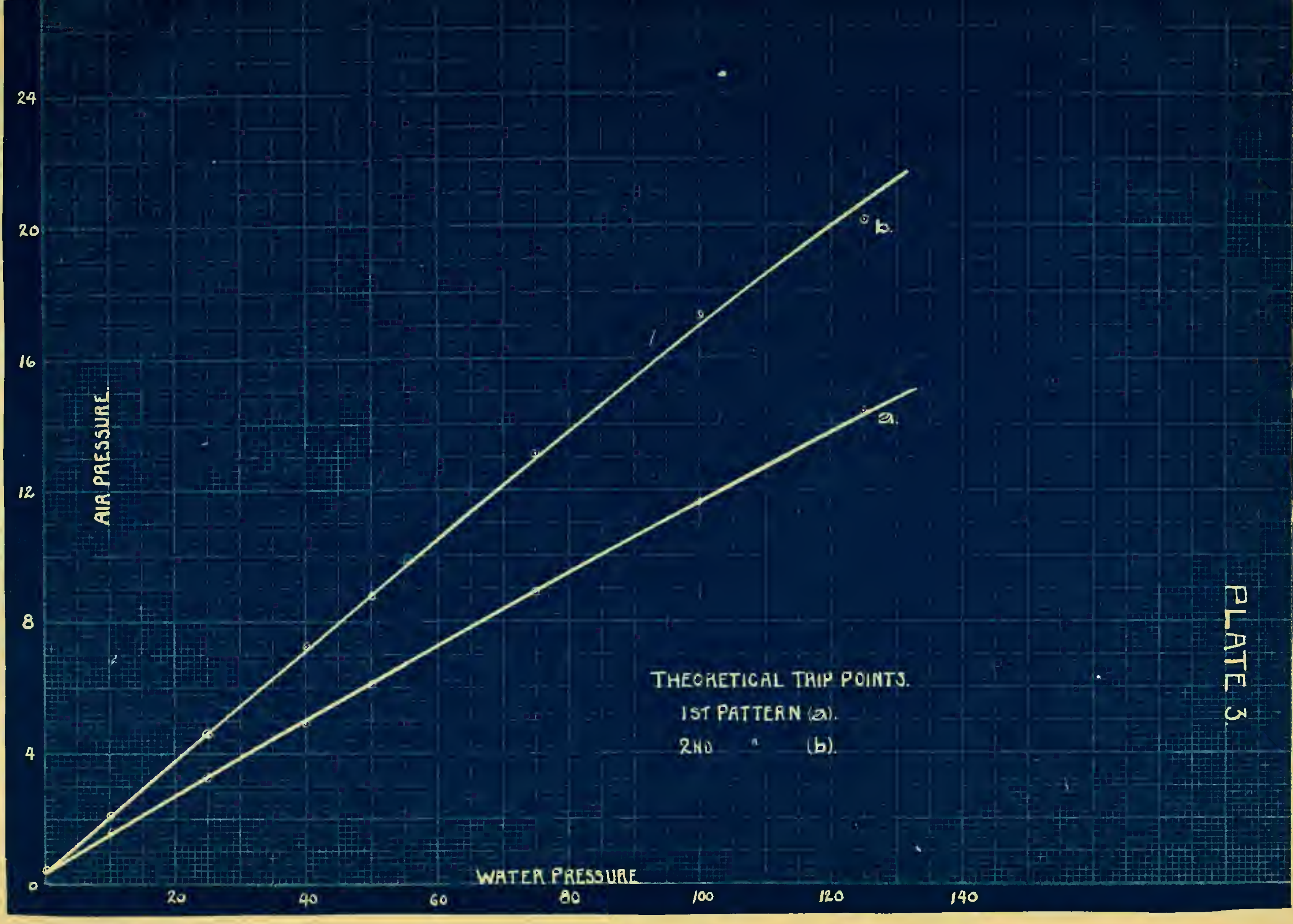
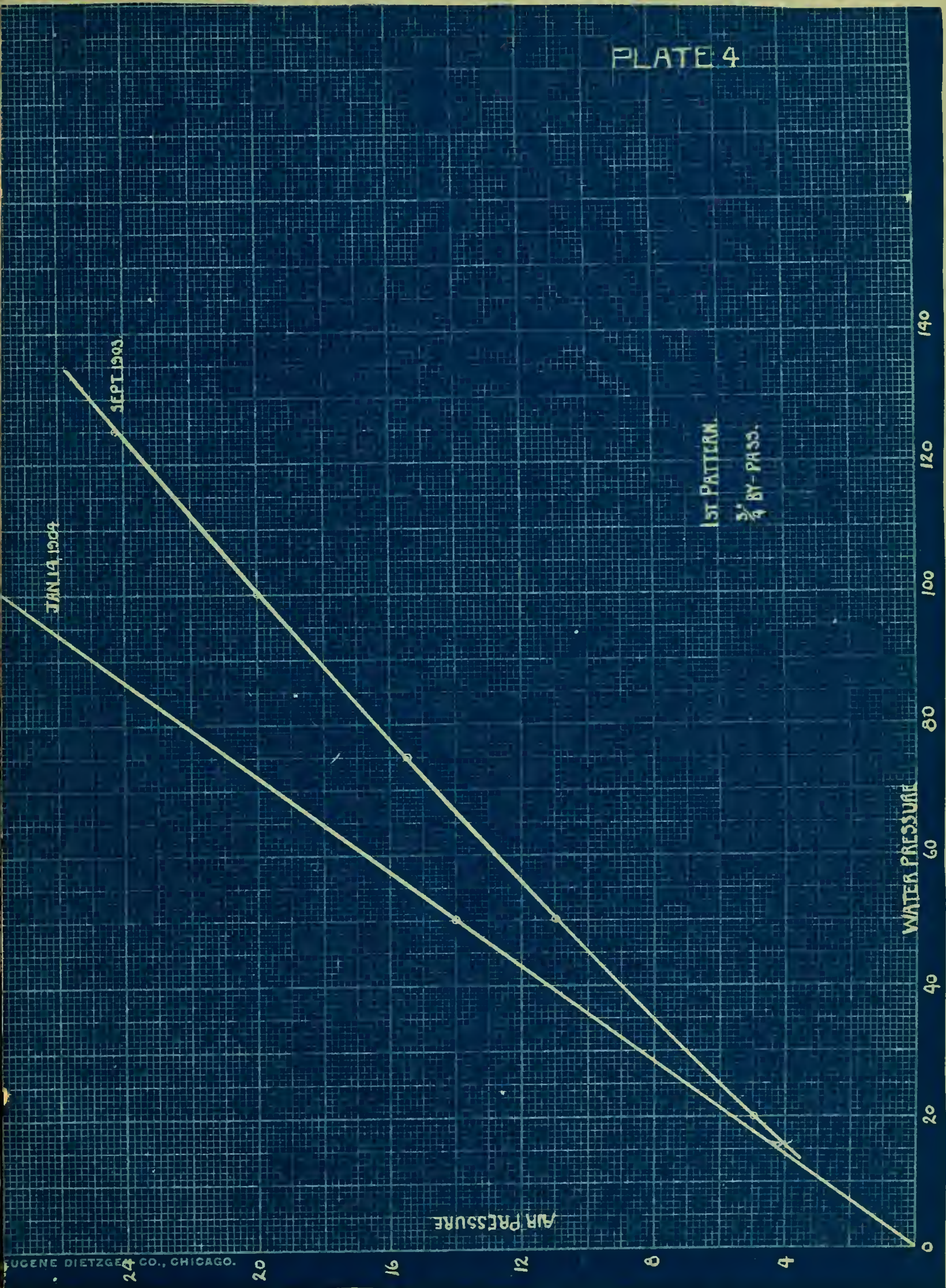


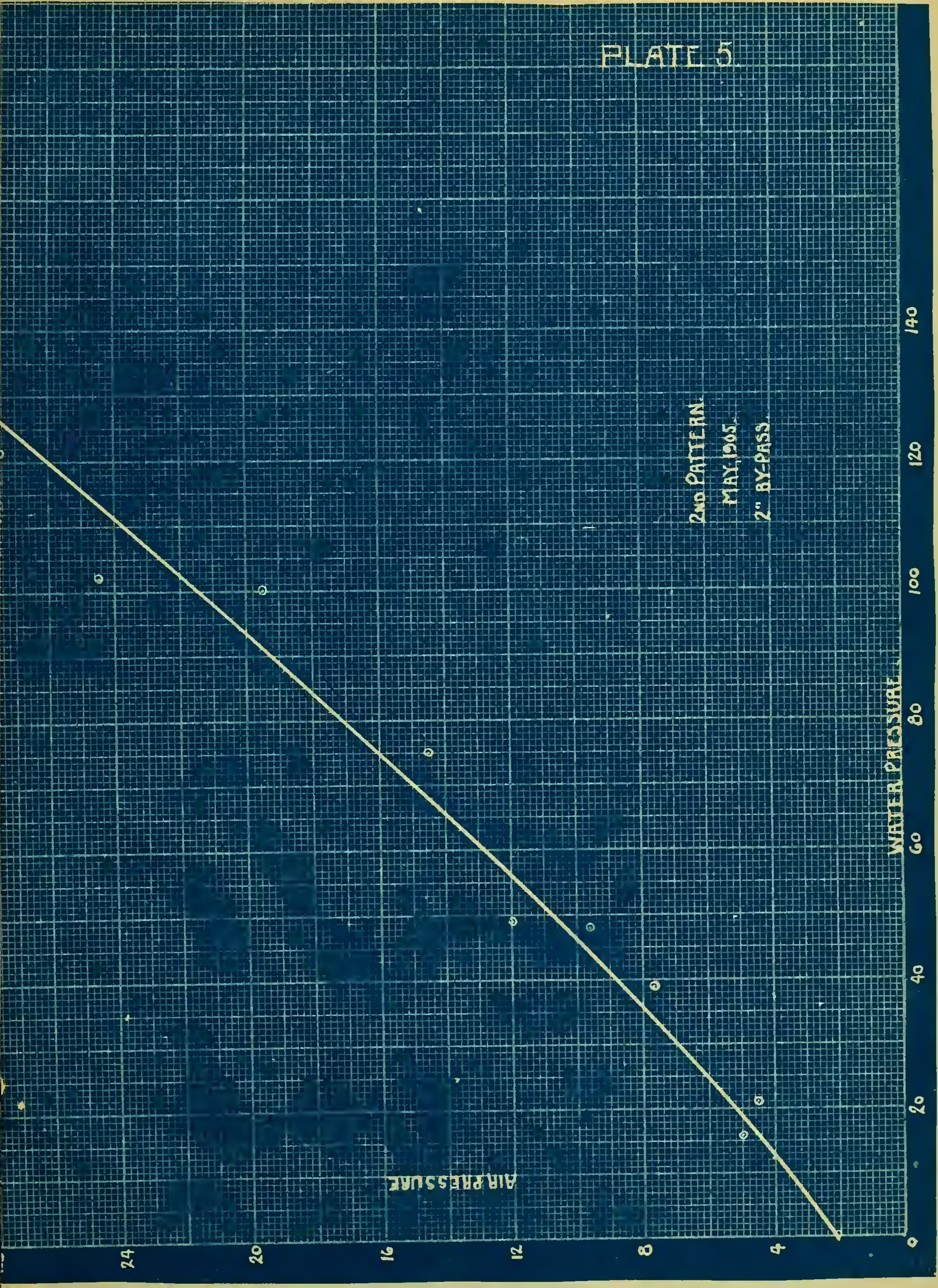
PLATE 3.
THEORETICAL TRIP POINTS.
1ST PATTERN (a).
2ND " (b).
b.
a.
AIR PRESSURE.
WATER PRESSURE
0
20
40
60
80
100
120
140
4
8
12
16
20
24

PLATE 4



JAN.19.1904
SEPT.1903
1st PATTERN.
3/4 BY-PASS.
WATER PRESSURE
AIR PRESSURE
0
20
40
60
80
100
120
140
4
8
12
16
20
24
EUGENE DIETZGEN CO., CHICAGO.

PLATE 5.



2ND PATTERN.
MAY, 1905.
2" BY-PASS.
WATER PRESSURE.
AIR PRESSURE
0
20
40
60
80
100
120
140
4
8
12
16
20
24

FIRST PATTERN. (3/4" By-Pass).

Water hammer occurred at 38#, 58#, 67#, 87#, 113.8# water pressure. At all other pressures above 25#, movable member found jammed. Time necessary for system to equalize varied from 50 to 70 secs. Water hammer was also produced on suddenly opening discharge valve at those pressures where water hammer occurred on "firing". At the pressures which the movable member jammed, no water hammer resulted on suddenly opening the discharge valve. No doubt the jamming of movable member on "firing" prevented this, as will be seen later on. The seats leaked badly at all pressures. On account of the tendency of the movable member to stick on "firing", a series of tests were made with movable member not set but resting on bottom of chamber (F). The water pressure was raised to 80#. The discharge valve was suddenly opened, The object of this series of tests was to pick up movable member and produce water hammer.

Water pressure, 78#,- opening discharge valve violent hammer resulted; 68#, same result; 62#, no hammer, but valve again jammed; 53#, violent hammer again resulted; 42#, no hammer, nor was movable member stuck.

Drop in water pressure over valve noted frpm gauge readings on air and water side found to be about 15# in all cases. As a rule, movable member was found jammed about 1/4" above rubber ring in chamber (F). At 76.9# water pressure movable member had turned a quarter of one revolution and was so tightly jammed that considerable force was necessary to loosen it. In most cases when movable member jammed it could be loosened by use of hand alone. Another curious

[illegible]

[illegible]

[illegible]

[illegible]

happening occurred at 38# and 88# water pressure where movable member was found jammed after water hammer had taken place.

The mercury gauge, which measures the difference in pressure between the two chambers, varied from 4.1# to 22# on "firing", and 3.8# to 9.1# on opening the discharge valve, thus showing that there is pressure in the lower chamber and also that it is higher in the lower chamber than in the upper chamber, because the left arm of the mercury gauge which was connected to the lower chamber gave a negative reading.

When valve trips a slight noise is heard, made by movable member dropping. This noise is not the familiar thud heard when metal strikes rubber. Also, the pressure rises slowly in the system, indicating that the movable member has not dropped full distance, thus having a throttling action and obstructing the flow. When the valve acted as above the movable member was found jammed. This happened in a large number of the tests. The jamming is caused by the fact that the guides are too short, and consequently do not start the movable member on its downward travel properly. There is also some play between guides on movable member and valve body, and since there is considerable pressure from above, if the movable member does not start down straight or is not kept in vertical position by the guides, it can easily become jammed, thus throttling the valve and rendering it inoperative.

When valve does not jam on "firing", it is immediately thrown back on its seats, vibrating so as to cause

water hammer in system, as shown by violent fluctuation of gauge needles. The probable reason for water hammer is the accumulation of pressure in chamber (F). Water hammer starts in at about 40#, never below this pressure. At the higher pressure the hammer is so violent as to injure the seats, which partly accounts for their poor condition.

The trip points are fairly uniform. The curve drawn through these points is very much steeper than the theoretical curve; also very much steeper than the curve obtained from the tests made at the Underwriters' Laboratories in September, 1903 and January, 1904.

The increase in air pressure necessary to hold movable member against water pressure is due to corrosion and wear of seats. The violent water hammer to which the valve has been subjected during the 3 years test at the laboratory has injured the seats to a marked extent, and thus a higher air pressure is necessary to make the seats tight.

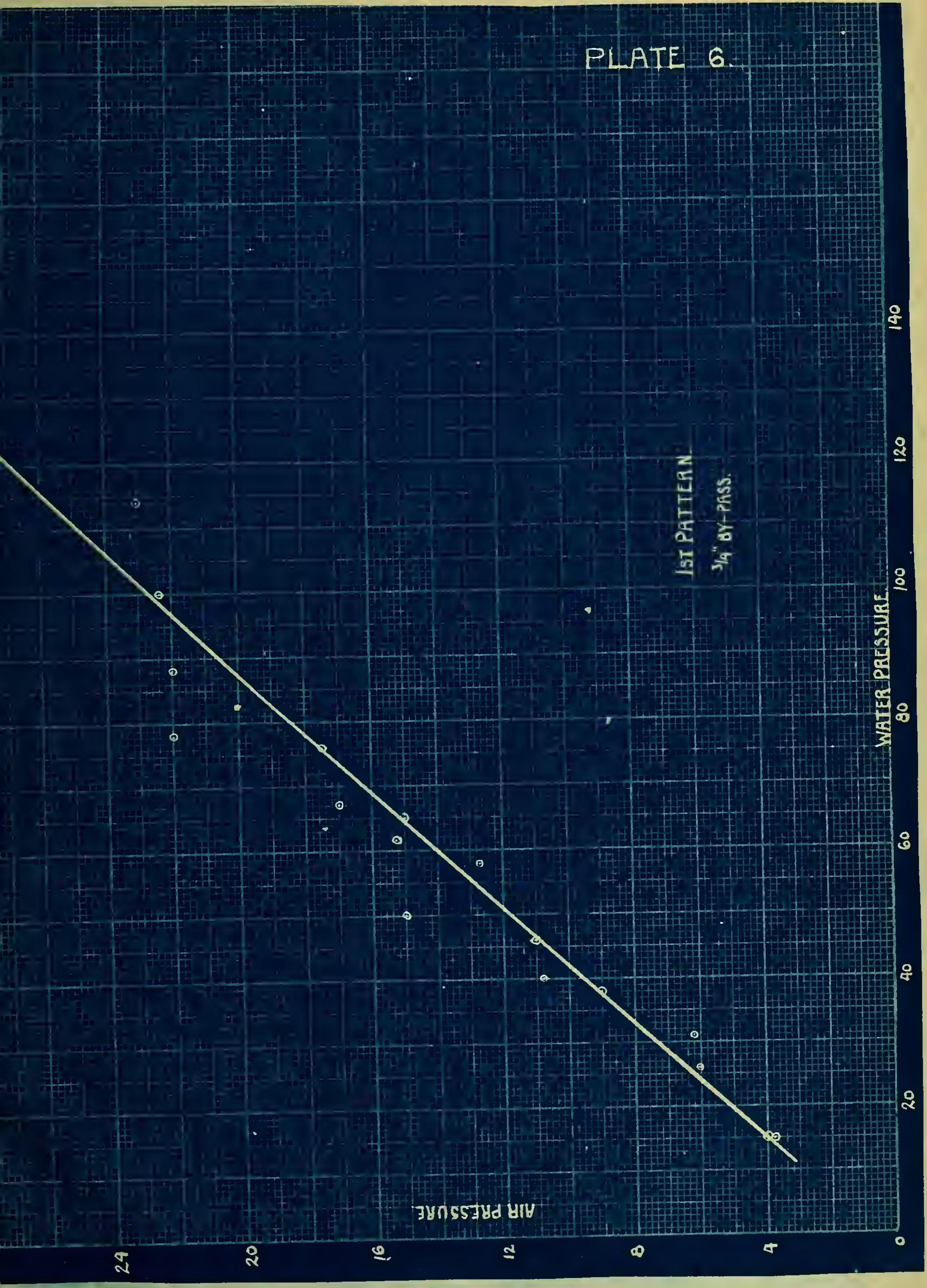
In order to determine the vertical travel of the movable member, a rod 1/8" in diameter and 6" long, fitted with a stuffing box, was used. The stuffing box was threaded and screwed into bottom of chamber (F). The valve was set and the rod pushed up against the under side of movable member. When the valve "fired" the rod was pushed down. The distance it is pushed down measures the vertical travel of the movable member.

With a water pressure of 9 lbs., the movable member drops full distance. With 23# water pressure, movable member does not drop full distance on "firing". System equalizes in

one minute, movable member then drops full distance. With 40# water pressure, movable member jammed, making only a small part of vertical travel. From the results of the data obtained, it is readily seen that the movable member does not drop full distance, even with water pressures as low as 23#,- again showing that the flow is obstructed.

At the end pf this test, the 3/4" by-pass was taken apart, and on examination of piping of by-pass it was found to be badly corroded. Actual diameter of pipe measured 9/16" at the union, 3/16" less than original diameter of pipe. Thus the 3/4" by-pass is really a 1/2" by-pass, and is later on compared with the second pattern with a 1/2" by-pass.

PLATE 6.


1st PATTERN.
3/4" BY-PASS.
WATER PRESSURE
AIR PRESSURE
0
20
40
60
80
100
120
140
4
8
12
16
20
24

FIRST PATTERN (2" by-pass).

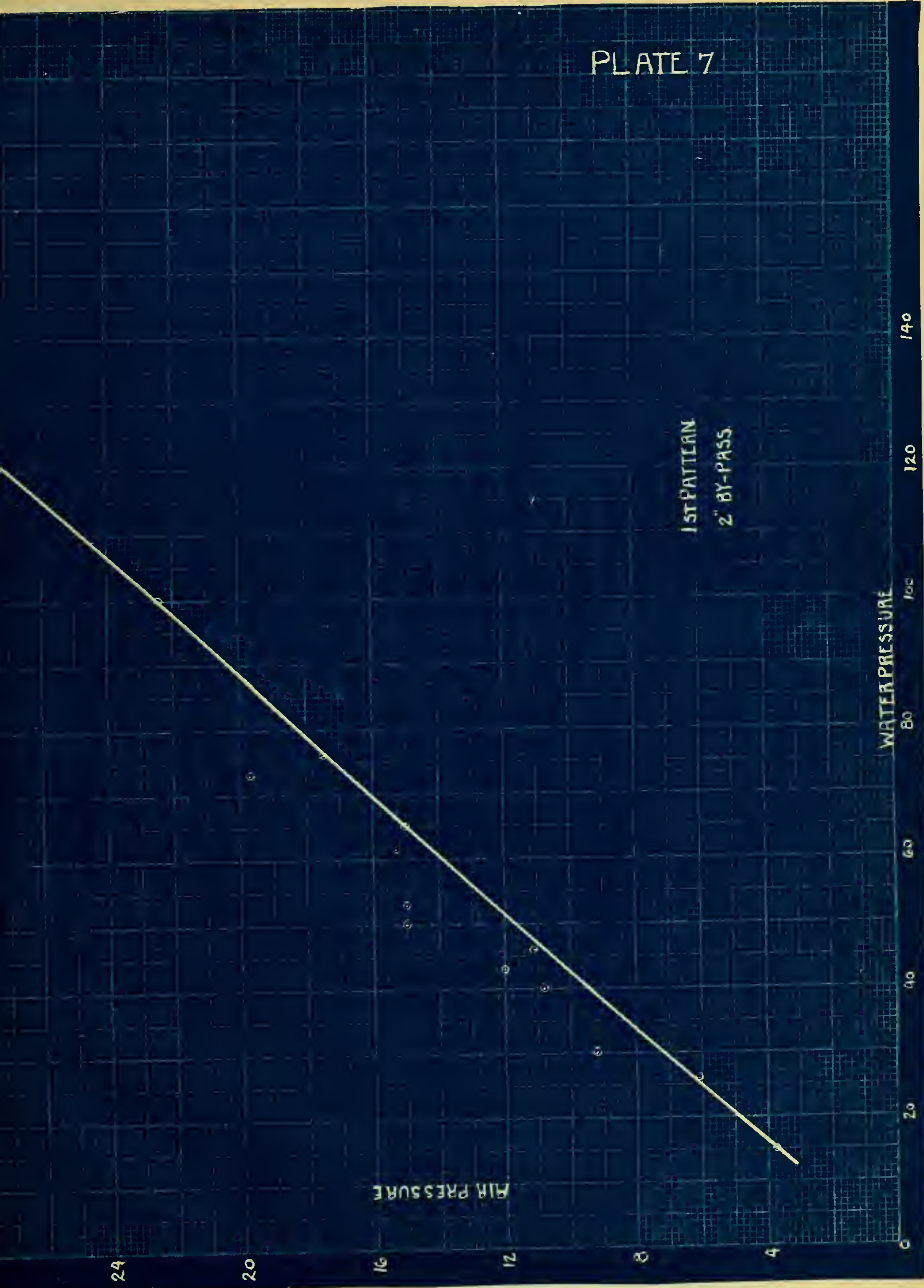
As stated before, the 2" by-pass in this test was inserted in the bottom plate of the valve. In "firing" the valve, the 4" gate was slightly opened until the valve fired, and as soon as the pressure on both sides of the valve equalized, which it did in less than 12 seconds, the gate was quickly opened. No water hammer was obtained either before or after the discharge was fully opened. In setting the valve the movable member jams easily, i.e., the guides stick in the opening through which they pass. When high water pressure is used it is necessary to use care in turning the pressure on the valve unless large air pressure is carried. In one instance when a water pressure of 100 lbs. was rapidly turned into the valve with 25 lbs. air pressure on the system, the valve immediately "fired". When the water pressure is turned on slowly, this trouble is eliminated. No continuous notes were taken of the loss in pressure over the valve, but it was noticed that when the pressure on the water supply was about 40 lbs., the pressure on the sprinkler system was 15 lbs. less.

For five of the "firing points" the mercury gage was used to determine the difference in pressure between A. and F. The gage was connected the same as in the tests on the 3/4" by-pass connection, and in every case the pressure was greater in the lower chamber. As shown in the data, the pressure in F. exceeds that in A. from 2 lbs. to 20 lbs. before opening the discharge valve, and from 4 lbs. to 10 lbs. after opening. In order to determine whether it was possible to pick up the

movable member when it was positively at the end of its travel, the face plate in the lower chamber was taken off and the movable member placed squarely on the bottom. The plate was then replaced and the water pressure turned on slowly, so that the pressure in the system rises gradually without any chance for the movable member being picked up. Then with 87 lbs. pressure on the system, the discharge was opened wide and the pressure lowered to 30 lbs. No water hammer resulted and the flow was unrestricted. The pressure in the lower chamber was about 10 lbs. more than in the upper.

During all these tests, when the valve was set, a large amount of leakage from the intermediate chamber was noted.

PLATE 7


1st PATTERN
2" BY-PASS
WATER PRESSURE
0
20
40
60
80
100
120
140
AIR PRESSURE
4
8
12
16
20
24

SECOND PATTERN. (1/2" By-Pass).

With this size of by-pass we have a condition which is nearly parallel with that under which the first pattern was tested when the 3/4" by-pass was used (caused by the corrosion in the 3/4" pipe used on the first pattern). In all, twelve tests were made with this size of by-pass, and the results show that this pattern has the same objectionable features as the first pattern, when the passage between the upper and lower chamber is restricted. The action of the valve was very erratic, for in some instances it was not possible to get water hammer when the conditions were such that this could be expected. In all instances of this kind the movable member was found jammed against its guides. With 14#, 22.2#, 24# water pressure, the valve "fired" without any difficulty, and when the discharge was opened wide no water hammer resulted and pressures equalized quickly. With 37#, 44#, 58.5#, 61.5#, 76#, 79#, 99.5# water pressure, when the valve"fired"a violent chattering occurred. This chattering was unlike the slam which was found in the first pattern, but apparently has the same effect on the seats and also restricts the flow no less. This chattering lasted from 10 to 20 seconds and then ceased, as the pressures on both sides of the valve became nearly equal. From 30 to 40 seconds were required for the pressures to equalize, and when it had done so, the discharge was opened wide. No water hammer of any kind occurred in any one of these seven cases, which may be accounted for by the fact that in each case the movable member was found jammed against its guides, when the face plate was removed.

With 22# water pressure a violent chattering occurred for 20 seconds after the valve "fired", and the pressure on the system equalized in 40 seconds more. The discharge was then opened wide. A "hammer" similar to that found in the first pattern occurred, and was followed by a very violent chattering. With 102.5# water pressure, the chattering lasted for 18 seconds, and pressure equalized in 30 seconds more. The discharge was then opened and the water allowed to escape. The water flowed for 30 seconds when a slam, followed by violent chattering, occurred. The pressure had fallen to 60# before the chattering began.

The mercury gauge was used in all of these tests and in every case the pressure in the lower chamber was found to be greater than that in the upper chamber.

This test demonstrates that the vital point in the "Ideal" dry pipe valve is the by-pass connection between the upper and lower chambers. In the following tests with different sizes of by-pass, the limit is quite clearly shown.

At first, in making these tests with different sizes of by-pass, a gate valve was inserted in the 2" by-pass in order to be able to quickly change the size of the opening between the two chambers. The gate valve used had very little "back lash" and as the pitch of its screw was easily found there was no difficulty in calibrating it so that a given number of turns would give an opening equivalent in area to any desired size of pipe. In order to do this, arcs were struck off with a radius equal to the radius of the opening through

the valve, and to the radius of the gate which closed the valve opening and with a distance between centers equal to the travel of the stem for a fraction of a turn of the valve wheel. The area between the arcs was then found with a planimeter. By the use of the pipe, areas as given in Kent's Mechanical Engineer's Handbook, it was then possible to determine the number of turns of the wheel which would give an area approximating that of a given pipe.

This method is open to two criticisms:-

1.- Method of obtaining areas is only an approximation.

2.- Shape of opening is not similar to that of a pipe of equivalent area.

In order to determine whether this method did give reliable results, the valve was taken out and pipe of different sizes substituted. This was done with the 1/2", 3/4" and 1" by-pass and the results checked so closely with those obtained by the approximate method that all the results have been tabulated together.

On the 1/2" by-pass tests, the pipe connection was used for 22.2", 44#, 58.5#, 79#, 102.5# water pressure. The other figures were taken by the approximate method.

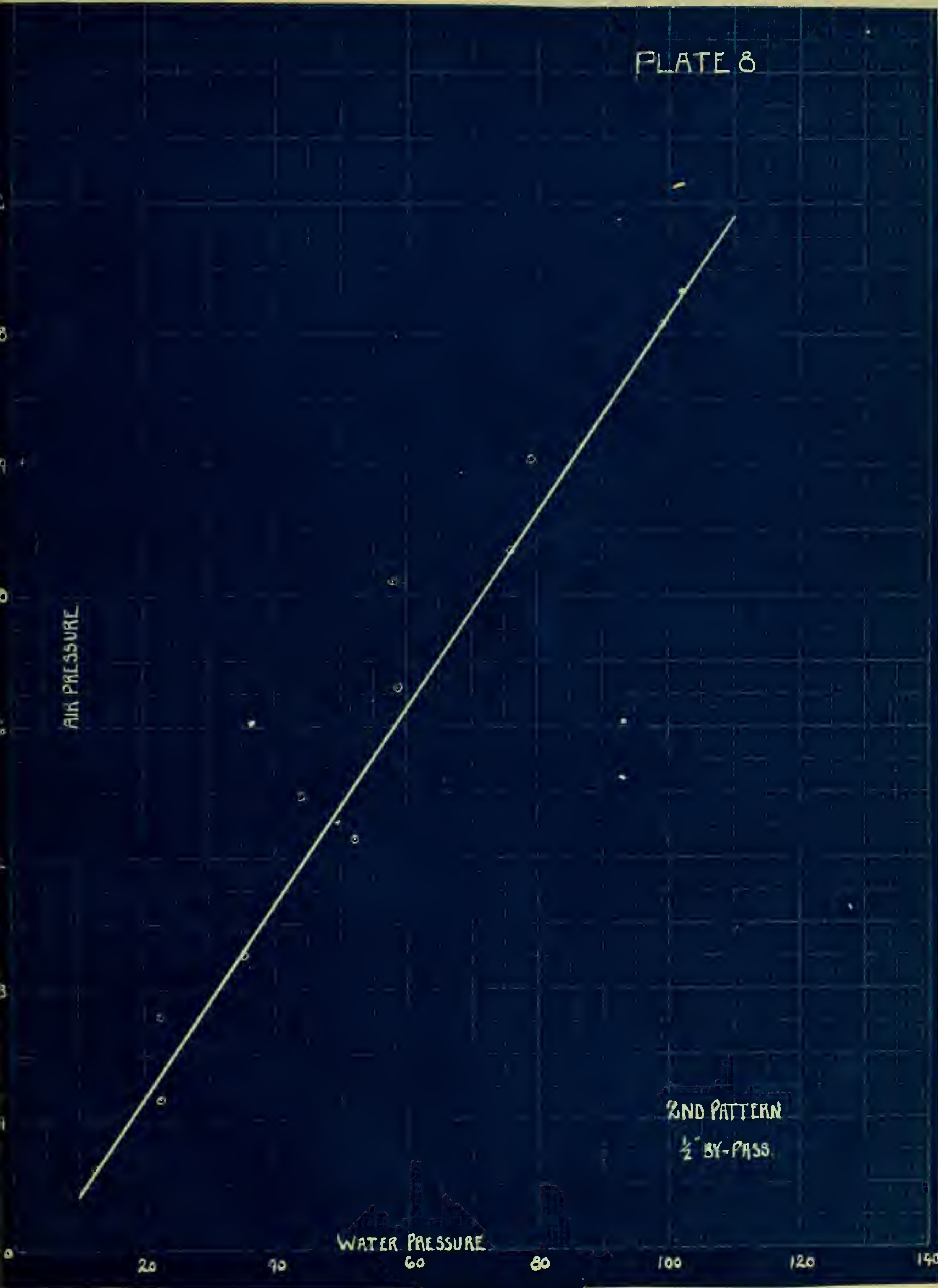


PLATE 8
AIR PRESSURE
WATER PRESSURE
0
20
40
60
80
100
120
140
2ND PATTERN
½" BY-PASS

SECOND PATTERN (3/4" By-Pass).

Water hammer occurred 77# and 101# of a very violent nature. At 113.5# no water hammer, but movable member found stuck, which accounts for lack of hammer at this high pressure. System equalizes in 10 to 35 seconds. No water hammer observed on opening discharge valve. Mercury gage readings vary from 9.6# to 23.7# on "firing", and from 4.5# to 10.7# on opening discharge valve. From the results of the data it is apparent that the critical point in the size of by-pass at which hammer occurs on suddenly opening discharge valve has passed, but the critical point in regard to hammer on "firing" has not yet been reached. Another interesting fact to be noted is that the movable member in the second pattern is also exhibiting a tendency to stick on "firing". The "firing" points are fairly uniform and the curves through them are not so steep as the 1/2" curve.

Pipe connection was used for the by-pass for 47#, (77# - 22.1#), 100.5#, 121.5#, 110#, 52.5#, 44# water pressure.

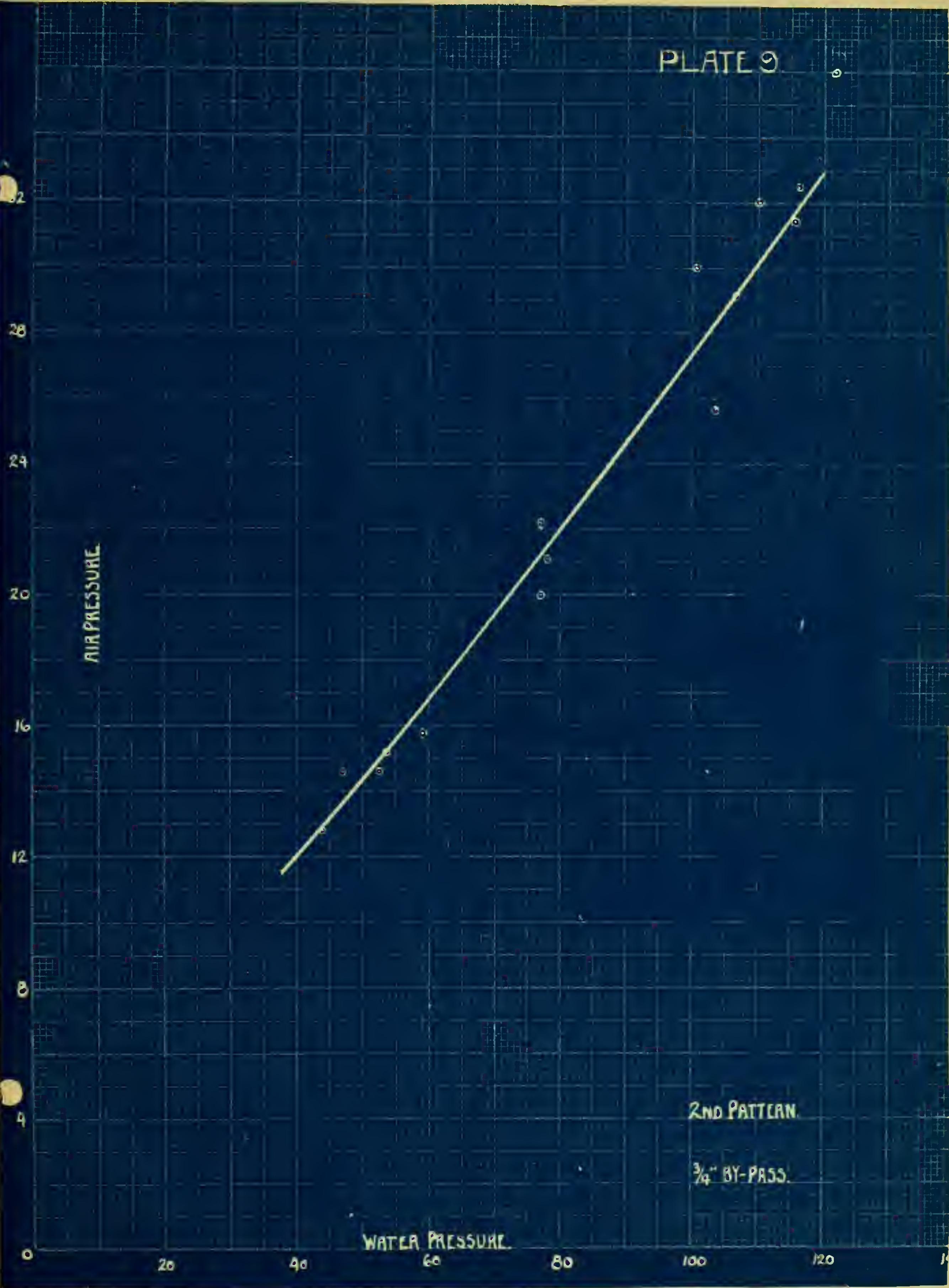


PLATE 9
AIR PRESSURE
WATER PRESSURE
2ND PATTERN.
3/4" BY-PASS.
0
4
8
12
16
20
24
28
20
40
60
80
100
120

SECOND PATTERN. (1" By-Pass).

Water hammer at 51.5#, 73.5#, 99#. Valve slammed at 40#. Time to equalize varied from 10 to 30 seconds. No water hammer opening discharge valve. Mercury gauge readings vary from 7.6# to 23.1# on "firing", and 2.8# to 8.6# on opening discharge valve. "Firing" points uniform. Curve not so steep as 3/4" curve.

. . . .

SECOND PATTERN. (1-1/4" By-Pass.)

No water hammer noticeable on "firing", but gauge needles fluctuated considerably at all pressures over 50#, and at 104.5# there was apparent movement of movable member on suddenly opening discharge valve. Time to equalize, 10 to 30 seconds. No water hammer on suddenly opening discharge valve. "Firing" points uniform. Curve not as steep as curve of 1" by-pass.

Although no hammer was noticed with this by-pass, yet the results of the data show that this size by-pass is not absolutely safe.

Pipe connection was used for by-pass for 49#, 50#, 56#, 62#, 77#, 100.5#, 119.5# water pressure.

[illegible]

[illegible]

. . . .

[illegible]

[illegible]

[illegible]

[illegible]

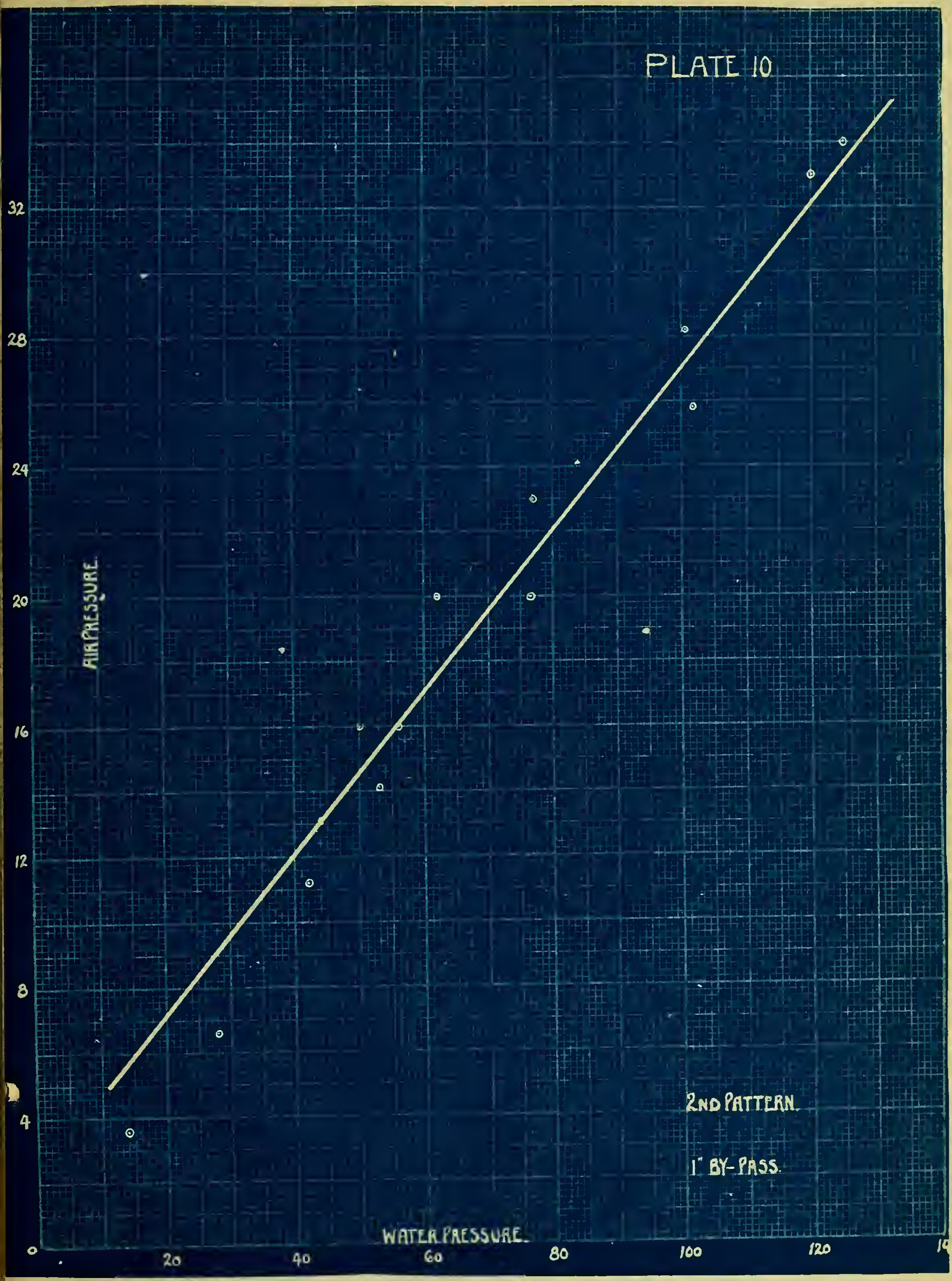


PLATE 10
AIR PRESSURE
WATER PRESSURE
2ND PATTERN.
1" BY-PASS.
32
28
24
20
16
12
8
4
0
20
40
60
80
100
120

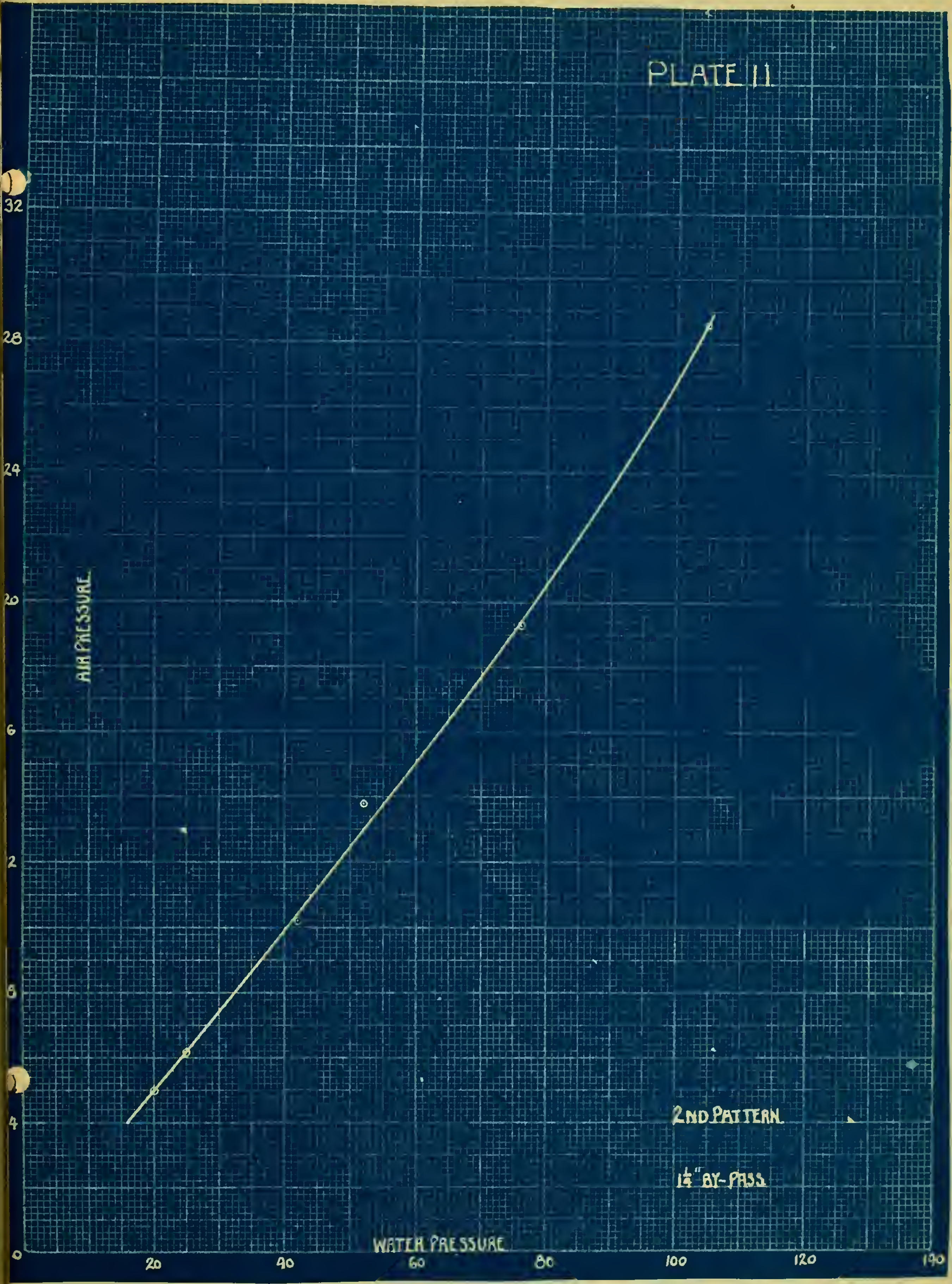


PLATE 11.
32
28
24
20
6
2
8
4
0
AIR PRESSURE
20
40
60
80
100
120
140
WATER PRESSURE
2ND PATTERN.
1¼" BY-PASS.

SECOND PATTERN. (1-1/4" By-Pass).

With this size by-pass it was not possible to obtain any water hammer, but a violent fluctuation of the mercury gauge and peculiar sounds in the valve when it "fired" would indicate that there was some movement of the movable member. Apparently, we have reached a size of by-pass which is nearly large enough to safely carry the flow from the lower chamber to the upper chamber.

The pressures equalized in about 30 seconds in every instance, and when the discharge was opened the mercury gauge indicated the large pressure as being in the lower chamber.

....

SECOND PATTERN. (1-1/2" by-pass.)

In no instance was water hammer obtained, and the mercury gauge always indicated the larger pressure to be in the lower chamber. This size of by-pass may be considered a safe one, and any addition to this dimension may be considered as a factor of safety.

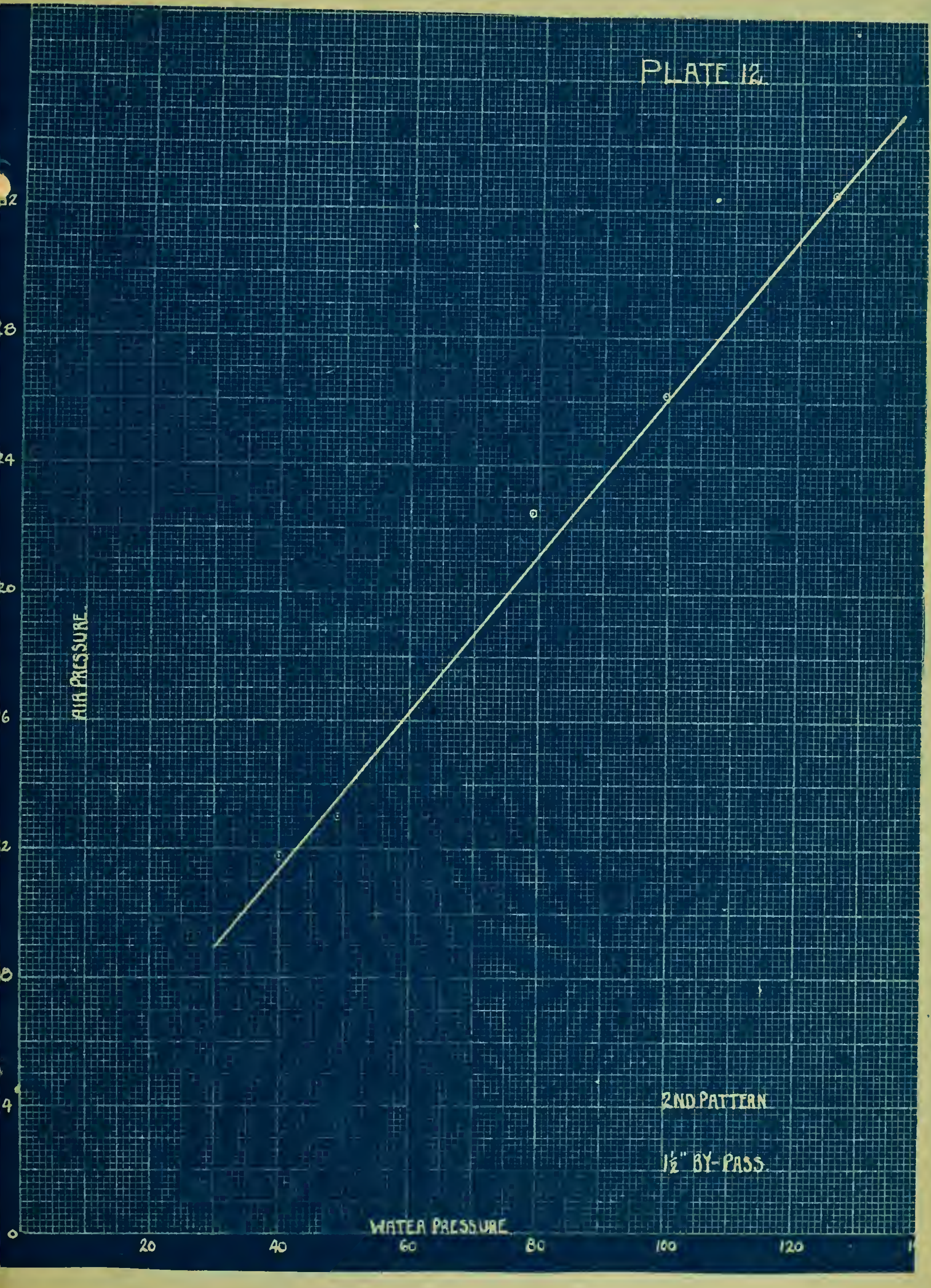


PLATE 12.
AIR PRESSURE.
WATER PRESSURE
2ND PATTERN
1½" BY-PASS.
20
40
60
80
100
120
0
4
8
12
16
20
24
28
32

SECOND PATTERN. (2" By-Pass.)

This is the normal by-pass for this pattern, and the tests will prove whether radical change has been made in the action of the valve. At no pressure was there any evidence of water hammer, and in all cases the pressure on the system equalized quickly (never longer than 15 seconds).

The mercury gauge in every instance indicated a larger pressure in the bottom chamber than in the upper chamber. Seemingly, the action of the valve with this size by-pass is very satisfactory.

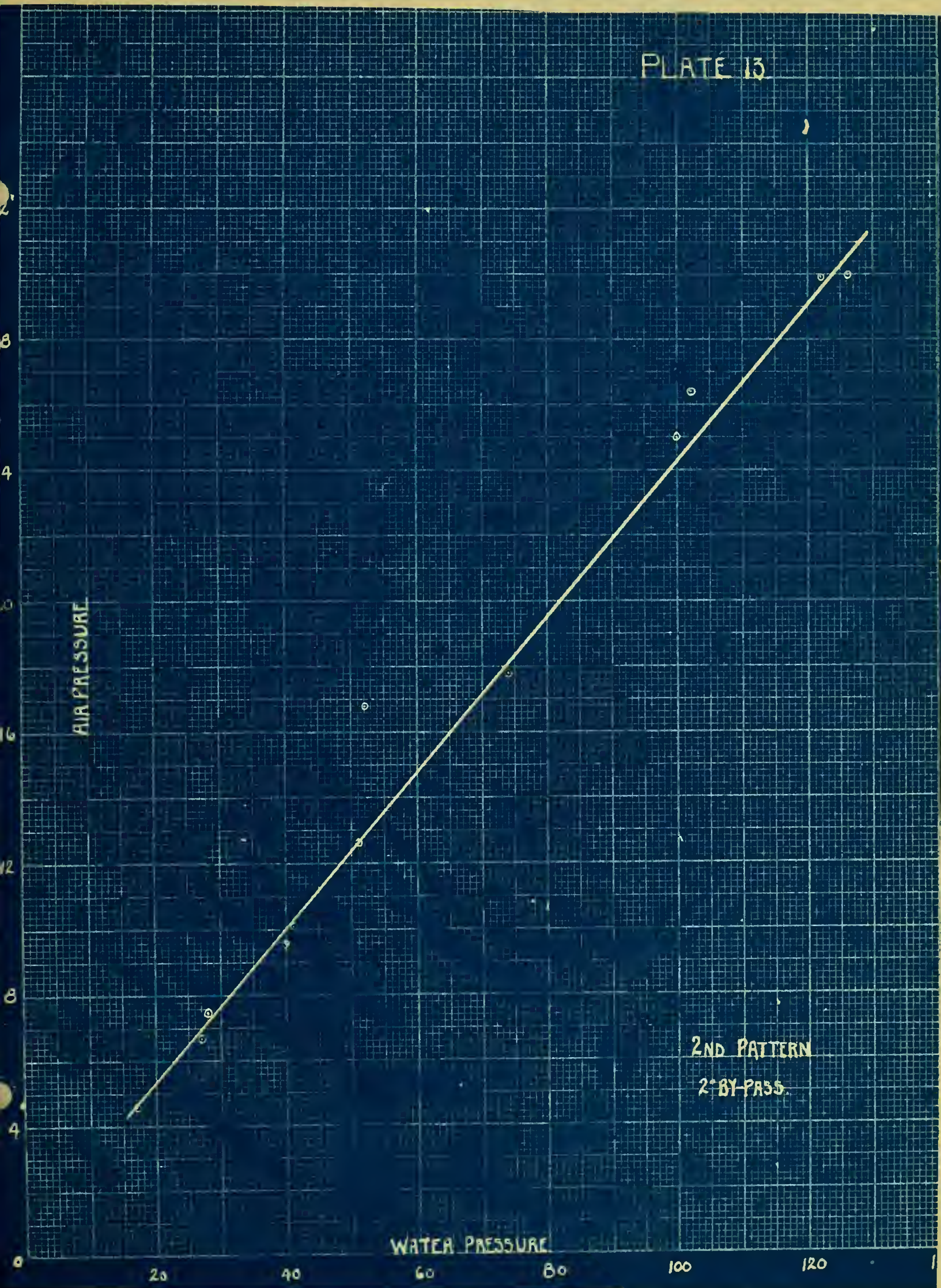


PLATE 13
AIR PRESSURE
WATER PRESSURE
2ND PATTERN
2" BY-PASS
20
40
60
80
100
120
4
8
12
16

1st PATTERN.

B.O.D.V. = BEFORE OPENING DISCHARGE VALVE.
A.O.D.V. = AFTER " " " .

SEPT. 1903.		JAN. - MAR. 1906.															
3/4" BY-PASS.		3/4" BY-PASS.				2" BY-PASS.				1½" BY-PASS.				2" BY-PASS.			
WATER PRESSURE	AIR PRESSURE	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.
20*	5.0*	13.0*	3.6*	4.15*	*	15.0*	3.8*	*	* 2.37	* 42.	* 11.7	* 8.5	* 3.72	* 17	* 4.6	*	*
50	11.0	15.0	4.0			26.0	6.1		2.26	51.5	19.0	12.75	4.51	27	6.7	4.63	1.81
75	15.5	22.0	6.0			30.0	9.2	9.05	4.85	79.	22.5	18.1	5.1	28	7.45		
100	20.0	25.0	7.5	13.0	4.0	40.0	10.7		6.8	99.5	26.1	22.7	6.55	40.1	9.8	6.3	2.37
125	24.25	30.1	6.2			43.1	12.0	12.2	8.5	125.5	32.5			91.1	10.1		
THEORETICAL TRIP POINTS.		38.1	9.1			50.0	15.0		8.5					51.	11.7		
0	.47	40.1	10.0	14.7	3.85	53.0	15.0	19.1						51	12.5	7.45	9.07
10	1.59	40.1	12.4	19.8	9.05	61.5	15.3							72.	16.8		
25	3.27	50.0	12.0	15.8	9.1	73.0	19.7	20.9						79.	17.8	12.5	9.6
40	4.93	52.0	19.1	OFF SCALE	8.3	76.0	17.5							99.9	25.0		
50	6.08	58.0	12.7			100.0	22.4							101.9	26.4	14.2	5.3
75	8.87	67.0	17.0			100.0	22.3							121.9	29.9	17.6	6.2
100	11.64	77.0	20.1	22.0		122.0	27.5							126.	30.0		
125.	14.42	78.0	22.15														
		88.0	22.15														
		119.0	23.2														

IDEAL VALVE
TRIP POINTS.

B.O.D.V. = BEFORE OPENING DISCHARGE VALVE
A.O.D.V. = AFTER " " "

1ST PATTERN.

SEPT. 1905.		JAN. – MAR. 1906.							
¾" BY-PASS.		¾" BY-PASS.				2" BY-PASS			
WATER PRESSURE	AIR PRESSURE	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.
20*	5.0*	13.0*	3.6*	4.15*	*	15.0*	3.8*	*	*
50	11.0	15.0	4.0			26.0	6.1		
75	15.5	22.0	6.0			30.0	9.2	9.05	4.5
100	20.0	25.0	7.5	13.0	4.0	40.0	10.7		
125	24.25	30.1	6.2			43.1	12.0	12.2	5.6
THEORETICAL TRIP POINTS.		38.1	9.1			50.0	15.0		
0	.47	40.1	10.0	14.7	3.85	53.0	15.0	19.1	7.8
10	1.59	40.1	12.4	19.8	9.05	61.5	15.3		
25	3.27	50.0	12.0	15.8	9.1	73.0	19.7	20.9	10.2
40	4.93	52.0	19.1	OFF SCALE	8.5	76.0	17.5		
50	6.08	58.0	12.7			100.0	22.4		
75	8.87	67.0	17.0			100.0	22.3		10.2
100	11.64	77.0	20.1	22.0		122.0	27.5		
125.	14.92	78.0	22.15						
		88.0	22.15						
		119.0	23.2						

THEORETICAL		MAY 1905					
TRIP POINTS.		2" BY-PASS		½" BY-PASS.			
WATER PRESSURE	AIR PRESSURE	WATER PRESSURE	AIR PRESSURE	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.
0*	.38*	0*	2.1*	14*	2.5*	4.5*	[illegible]
10	2.07	16.5	5.0	22.2	7.2	7.9	[illegible]
25	4.62	53	7.7	24.	4.6	8.9	[illegible]
40	7.14	48	9.6	37.	9.0	9.55	[illegible]
50	8.83	49	12.0	44.	13.8	11.8	[illegible]
75	13.08	79.9	14.5	52	12.5	10.7	[illegible]
100	17.32	100.	19.5	58.5	17.1	12.4	[illegible]
125	21.6	102.	29.5	61.5	20.3	19.4	[illegible]
		121	27.5	76	21.2	19.1	[illegible]
		140	31.5	79	24.0	16.4	[illegible]
				99.5	28.1	17.5	[illegible]
				102.5	29.2	20.3	[illegible]

2ND PATTERN.

JAN. – MAR. 1906.																			
¾" BY-PASS.				1" BY-PASS.				1¼" BY-PASS.				1½" BY-PASS.				2" BY-PASS.			
WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.	WATER PRESSURE	AIR PRESSURE	MERCURY GAUGE B.O.D.V.	MERCURY GAUGE A.O.D.V.
[illegible]	12.7*	9.6*	4.57*	19.*	3.6*	*	*	20*	5.*	4.65*	2.37*	42.*	11.7*	8.5*	8.72*	17*	4.6*	*	*
[illegible]	14.6	13.2	5.3	28	6.6	7.65	2.83	27.	6.2	8.8	2.26	51.5	19.0	12.75	4.51	27	6.7	4.63	1.81
[illegible]	19.8	13.1	5.45	42.	11.2	12.9	3.64	42	10.1	13.0	4.85	79.	22.5	18.1	5.1	28	7.95		
[illegible]	19.6	14.95	5.3	44.	13.1	9.6	3.95	59	13.8	15.0	6.8	99.5	26.1	22.7	6.55	40.1	9.8	6.3	2.37
[illegible]	15.2	11.6	5.5	50	16.			76.	19.2	17.2	8.5	125.5	32.5			41.1	10.1		
[illegible]	15.8	15.3	6.5	53	19.1	13.9	5.45	104.5	28.6	22.5	8.5					51.	11.7		
[illegible]	20.1	14.7	7.35	56	16.	11.5	4.75									51	12.5	7.45	4.07
[illegible]	22.1	16.9	7.35	62	19.9	11.8										72.	16.8		
[illegible]	21.1	16.6	7.3	76.5	19.9	17.1	6.9									74.	17.8	12.5	4.6
[illegible]	30.0	23.2	8.8	77.	22.9	15.3	6.9									99.9	25.0		
[illegible]	25.6	16.1	10.2	100.5	28	20.3	8.1									101.9	26.4	14.2	5.3
[illegible]	29.1	21.0	9.6	101.5	25.7	23.1	8.5									121.9	29.9	17.6	6.2
[illegible]	32.0	23.0	9.2	119.5	33.0											126.	30.0		
[illegible]	31.5	23.7	10.7	125.	34.0														
[illegible]	32.5		9.6																
[illegible]	36.0																		

DIMENSIONAL COMPARISONS.

First Pattern.	Second Pattern.
1. AREAS RECEIVING WATER PRESSURE.	
Dias., 5-1/8" x 4-3/8" Area upper 20.62 sq. in. Area lower 15.03 sq. in. Area effective 5.59	Upper seat dia., 4-3/16" Spring inside dia., 4-5/8" Spring width 3/8" Lower area 22.698 Upper area 13.800 Effect' area 8.898 sq.in.
2. AREAS RECEIVING AIR PRESSURE.	
Dia. 8-1/4" Area 53.46 sq. in.	Dia. 7-13/16" Area 47.93 sq. in.
3. WEIGHT OF MOVABLE MEMBER, EMPTY & DRY.	
20# 13.5 oz.	19# 3 oz.
4. WEIGHT OF MOVABLE MEMBER FILLED WITH AS MUCH WATER AS IT WILL HOLD.	
23# 14.5 oz.	19# 6.75 oz.
5. CONTACT AREAS OF CORRESPONDING SEATS.	
Upper water 2.5 sq.in. Lower water 5.9 sq.in. Air 7.78 sq. in.	Upper water 1.21 sq. in. Lower water 1.81 sq. in. Air 3.75 sq. in.
6. MAXIMUM VERTICAL TRAVEL OF MOVABLE MEMBERS.	
1-15/16"	2-1/8"
7. CLEARANCE BETWEEN RUBBER RING AND BODY OF VALVE IN LOWER AIR CHAMBERS.	
Ring dia. 8-3/32" Body dia. 9-1/8"	Ring dia. 8-1/4" Body dia. 9"
8. SIZE OF PIPE CONNECTIONS BETWEEN UPPER AND LOWER AIR CHAMBERS.	
3/4" pipe	2" pipe

9. DIMENSIONS BETWEEN CENTERS AND FACES OF INLET AND OUTLET FLANGES.

Upper 14-3/8" Lower 7-1/4"	Upper 15-5/8" Lower 7-1/2"

10. BOLT CIRCLES, BOLT HOLES, AND DRILLING TEMPLATE OF INLET AND OUTLET FLANGES.

Bolt circ.dia. 7-1/2" 8-1/2" bolts	Bolt circ. dia. 7-1/2" 8-1/2" bolts

In calculating the area receiving water pressure in the new valve, the entire width of the spring exposed to pressure is taken as effective and no account is made of the elasticity of the spring. This will make a difference between the actual and the theoretical "firing" points.

DISCUSSION.

In our introduction we stated our purpose to be the discovery of the cause of the failure of the first pattern of the Ideal Dry Pipe Valve and to compare the first pattern with the second pattern, and, as the statement goes, the results have been satisfactory. However, the subject is by no means an exhausted one, and further investigation would certainly bring to light more peculiarities of this unique device. When we say that it is a unique device there need be no reservation, for the title is proved appropriate when we examine the foregoing data.

On account of the construction of the valve, it was impossible to observe its internal action, so it was necessary to judge what actually took place by the sounds emitted, by the action of the mercury gauge, and by the gauge readings on the system. When the valve "fired", if the movable member dropped, a distinct thud was heard. When water hammer occurred, the first pattern gave off a sharp slamming noise, which was easily recognized as being caused by metal striking against metal. The second pattern with the smaller by-passes produces a chattering sound, which is caused by the vibration of the brass diaphragm.

The action of the mercury gauge is the same with both patterns:- Mercury ascends the left arm of the "U" tube, indicating that the pressure in the lower chamber (F) is higher than in the upper chamber (A). As the pressure on the system equalizes, the mercury drops back to zero, and, when the discharge is suddenly opened, the mercury again shows the

larger pressure to be in the lower chamber. When the valve "fires" and water hammer does not occur, the gauges show an almost immediate equalization of pressure, but if water hammer occurs, the pressure on the air side of the system drops to zero and then equalizes in a time which varies from 20 seconds to 70 seconds.

From the data collected, we find the cause of the failure of valve to be due entirely to the size of the by-pass connecting the two air chambers. The theory that the inoperative condition is due to the fact that water leaking past seats (P) and (Q) accumulates in (C) and (G), not in equal proportions but in greater quantity in (G), and from the latter chamber is passed into chamber (F) where its accumulation acts as a stop for the movable member, even after the valve has "fired", is acceptable. This stop is not a permanent one, unless the discharge from chamber (A) is so large that the flow from chamber (F) cannot bring the pressure in (A) to a point where it is equal to that in (F). If the flow from (A) is small, the pressure in (A) accumulates until it is equal to that in (F) and allows the movable member to drop to the bottom. That this is true is shown by the method mentioned on page (//). By means of the small plunger it was clearly proven that the movable member did not drop to the bottom of the lower chamber (F) when the valve "fired", but that it gradually settled to the bottom as the pressure equalized. The sudden opening of the discharge valve, when the pressures had equalized,

resulted in water hammer in both patterns when the smaller by-passes were used. That this water hammer was caused by the lifting of the movable member from the bottom of chamber (F) was proven by means of the plunger. The lifting of the valve can only be accounted for by the theory that the sudden rush of water through (C) into (A) creates a suction which lifts (D) to its seats with a heavy slam, and brings it to the point where the pressure in the lower chamber exerts its influence.

A summary of the data collected shows that both patterns of the valve are operative with a large by-pass between the upper and lower chambers, and likewise, both are inoperative when the by-pass is small. The determining feature in both patterns is the size of the by-pass, and this may be said to be the only reason for the failure of the first pattern. Of course, this by no means must be taken to convey the idea that this is the only objectionable feature present in either pattern.

In the first pattern, the two seats on one rigid body present mechanical difficulties in the manufacture and repair of the valve, and also affect its efficiency in operation. When the first pattern was new, the seats held water very satisfactorily, but use and corrosion during three years have worked a remarkable change. Noting "firing" points with 75# water pressure on the system, we will see that in 1903 15.5# air pressure was obtained, while in 1906 we find 20.1#. Other water pressures do not give the same results, but in general show that time increases the

"firing" point. The same is true of the second pattern, although to a less extent. This is shown clearly in the blue prints which show curves of increasing steepness for successive tests. An interesting and rather puzzling point is the fact that the curves for the second pattern show that the steepest curve is obtained with the 1/2" by-pass, and that the curves become less steep with every increase in the size of the by-pass. It might be thought that this is entirely due to error in the selection of an average curve through the points, but if such is the case, it is a rather remarkable coincidence, for the curves were all drawn before the circumstance was noted. The only explanation of this matter that occurs to us at present, is that it may be due to the method of determining the "firing" points. On account of the construction of the valve it was not possible to see when the valve "fired", so sound alone had to be depended upon. This, no doubt, would affect the accuracy of the points to a certain extent.

It was noted that water hammer was prevented in a number of instances by the movable member jamming. This jamming occurred principally in the first pattern, but was also found in the second pattern when the 1/2" and 3/4" by-passes were used. With the first pattern the movable member jammed so hard in some instances that it was necessary to use considerable force to release it. The jamming is caused by the guides not holding the movable member exactly in the center of the valve. The reason for the improvement

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is the increased length of the guides.

Finally, we may say that both patterns of the Ideal Dry Pipe Valve act similarly when the same size of by-pass is used, but that although the size of the by-pass is the determining feature, the changes made in the second pattern render it superior to the first. The introduction of the flexible seat increases the tightness of the valve and reduces the need for frequent regrinding. Changing the passage between (C) and (G) makes the valve more self-contained, and also gives a larger passage for the equalization of pressure in these two chambers.

Experimentally, this pattern of the Ideal Dry Pipe Valve may be considered satisfactory, but it is another matter to predict the result of field experience. Sediment or large floating objects would so obstruct the by-pass or injure the seats as to render the valve inoperative, and for the final proving of the valve, we must wait for further experiments under severe conditions.

Arnold A. Hepp.
Earl J. L. Smith